Visual Moonbounce: Images and Video in Moonbounce Technology

Daniela de Paulis

Back in October 2009 I got in touch with the CAMRAS team (PI9CAM) at Dwingeloo radio telescope in The Netherlands, with a proposal for an artistic project.

For the last few years I had been thinking about moonbounce, in fact since first hearing an echo from the Moon I had been amazed by this technology. When I got in touch with CAMRAS I had the idea of moonbouncing some footage for one of my film projects. Jan van Muijlwijk (PA3FXB) replied enthusiastically to my suggestion and started looking into various possibilities, the result being that moonbouncing a video clip was not impossible but rather difficult – so why not still images instead, would that be an option? And so we started our collaboration.

Figure 1: Daniela de Paulis with the CAMRAS team at the Dwingeloo radio telescope

History and Development

Up till then I had the opportunity to read about and hear some moonbounced sounds on the Internet. Other artists used moonbounce in their work, the most well known examples of that being 'Echoes of the Moon' by American composer Pauline Oliveros and 'Earth-Moon-Earth' by British artist Katie Paterson. They both used moonbounce in their sound works. Pauline Oliveros created her piece 'Echoes from the Moon' in 1987, after watching on television the first Moon landing in 1969. She performed the piece several times, working with ham radio operators Dave Olean K1WHS in Maine and Mark Gummer N2IQ in Syracuse, New York. During her performances Oliveros sent sounds from her microphone to a phone line, receiving the echoes after approximately two and a half seconds. She also involved the audience, people used to queue in her

events and 'seemed to get a big kick out of hearing their voices return-processed by the Moon' ('Notes on Echoes from the Moon', Pauline Oliveros).

Twenty years after, in 2007, Katie Paterson used moonbounce in another remarkable work, called 'Earth-Moon-Earth', where she sent to the Moon and back, with the help of a group of radio amateurs in Japan, Beethoven's 'Moonlight Sonata' converted into Morse code. The moonbounced sounds were then converted back into notes and played as a piano piece [1].

Other artists used moonbounced sounds in their music or sound works – but what really triggered my curiosity was the possibility of 'seeing' the traces of the 768,000 kilometres journey to the Moon and back. What if moonbounce could communicate visually this amazing journey?

This is how I thought of moonbouncing visual data, and in my art projects I refer to this visual communication via the Moon as 'Visual Moonbounce'.

Being very often in The Netherlands for my artist residencies, contacting the CAMRAS team at Dwingeloo radio telescope was the most obvious option – and, as it turned out, the most appropriate one. Dwingeloo radio telescope is not only able to receive good enough quality pictures from the Moon, thanks to its 25 metres diameter and additional technical features, but was also open to this artistic collaboration.

Immediately after our initial contact, Jan started experimenting with possibilities of moonbouncing images using the MMSSTV software. The very first test was carried out on 6 December 2009 when Jan sent to the moon the portrait of his 3 metres dish in the back garden of his house. The signal was received by the Dwingeloo dish. In Jan's words: "We were thinking about asking some big dish stations to do a test with us, but on 6 December 2009 I was at home while the Dwingeloo dish was also on the air (a situation that does not happen very often) so I thought why not do a first SSTV try myself! I phoned Dwingeloo to suggest that I could send an SSTV signal, and so I did [...] Later on 26 February 2010 we successfully exchanged pictures with HB9Q in Switzerland and the first two way EME SSTV contact was made."

Figure 2: First image to be moonbounced to PI9CAM: Jan van Muijlwijk's 3 m dish

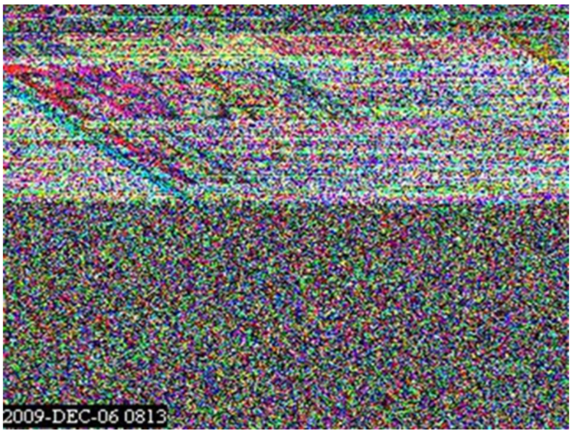

Figure 3: The result of the first experiment, 6 December 2009

The result of this first experiment was very promising, although the original image was not recognizable at this point. Several attempts followed until the moonbounced images started becoming more and more clear.

The noise showing in any moonbounced image is what makes it interesting and evocative of the long journey to the Moon and back. The radio signals containing the information of the image become weaker while travelling the long distance. This is one

of the causes for the distortion of the original colours and shapes in the image, other causes being the poor reflective qualities of the Moon's surface, the Doppler shift and the lunar libration, amongst others.

Figure 4: One of the first images ever to be moonbounced on SSTV (courtesy: NASA)

During transmission the MMSSTV software converts the colours and pixels of the image into sounds that are then converted into radio waves; these are sent to the Moon and after bouncing off they are received by Dwingeloo radio telescope, converted into sounds and then back into image using the same software. The sounds produced by each moonbounced image are unique to that image; in fact no two moonbounced images will ever be alike due to the continuously changing astronomical conditions.

Sending images via the Moon is not however a completely new thing. In the history of development of moonbounce technology, mainly carried out in its early days by the US Navy, it is possible to trace back the initial experiments with images. When the “Radar Division of the Naval Research Laboratory upgraded the Moon Relay system [...] by using the ultra high frequency (UHF) band [...] the experimental Moonbounce system was transformed into a fully operational lunar relay” [2]. This new, more efficient system was officially launched on 28 January 1960. “As part of the inaugural ceremonies, pictures of the aircraft carrier *USS Hancock* were beamed from Honolulu to Washington via the Communication Moon Relay system. The transmitted facsimile [see next page] featured thousands of *Hancock* officers and seamen spelling out ‘Moon Relay’ to a worldwide audience” [3]. “The completed system used eighty-four-foot-diameter (twenty-eight-meter-diameter) steerable parabolic antennas and 100-kilowatt transmitters installed at Annapolis, Maryland, and Opana, Oahu, with receivers at Cheltenham, Maryland, and Wahiawa, Oahu. The system operated at frequencies around 400 megahertz, it could accommodate up to sixteen teleprinter channels operating at the rate of sixty words per minute, and it was capable of processing teletype and photographic facsimiles” [4].

Another interesting example of visualizing the Moonbounce process is a study made by radio amateur Andrea Mancini (IW4CJM) “with the cooperation of the Radioastronomy Association 'Bagnara di Romagna', on how to ‘write’ on the Moon [...] The actual writing is obtained using audio tones within the transmitter’s audio band, so that, if *Spectran* is used to decode, numbers and letters will appear on the screen [...] I needed to increase

the letters' size from 100 to 800 Hz, using Spectran left-to-right scan. Subsequently, I have been able to obtain the same result with up/down Spectran scan, which is the normally used mode," says Mancini in his text for the EME conference in Florence in 2008.

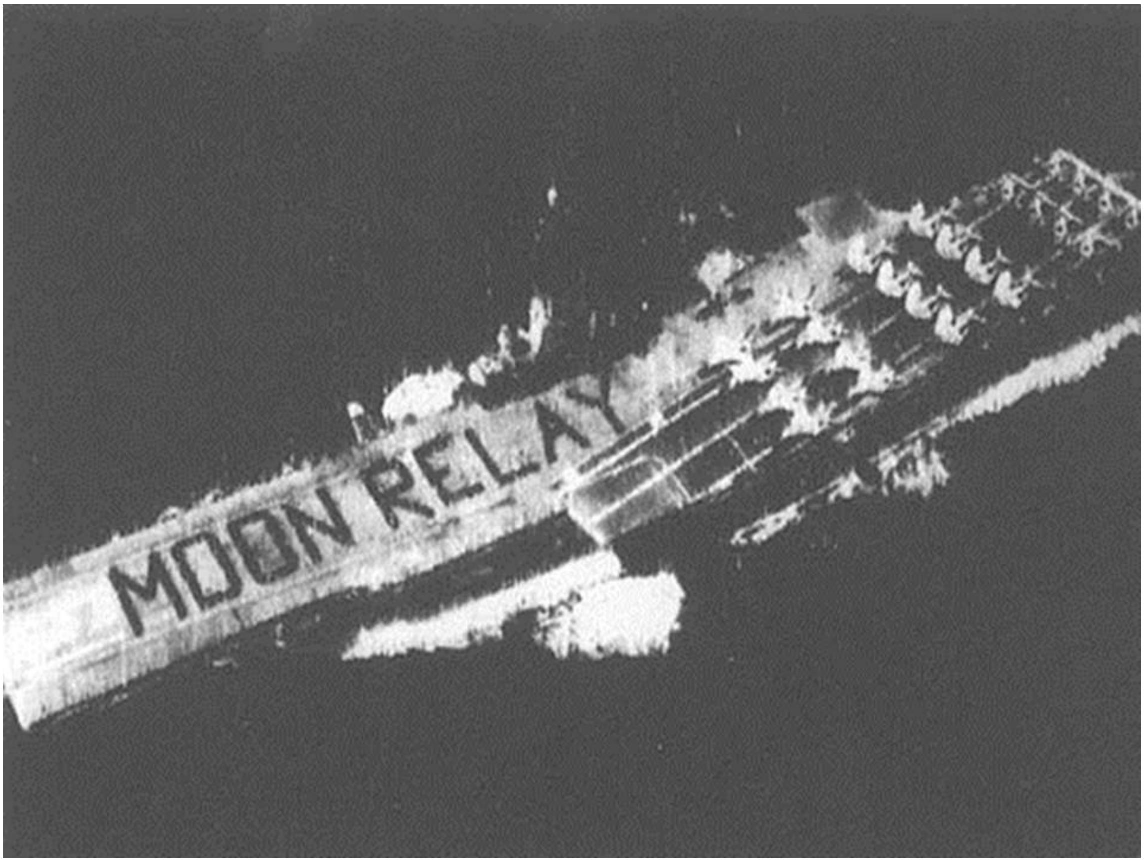

Figure 5: Facsimile picture of the USS Hancock with ship officers and crew spelling out 'Moon Relay'. This picture was transmitted via the Moon from Honolulu, Hawaii, to Washington, DC on 28 January 1960 (courtesy US Navy, NASA).

"After this change, I was ready to 'write' on the Moon, and the first tests, carried out on May 5, 2004, were successful [...] The signal from the 7-meter dish was sent while the dish itself was slowly moved at a steady speed across the surface of the moon, from the east to the west limb [...] While experimenting, I noticed that the text had a better definition if, instead of a single tone, two were used [...] I called this 'the painter's theory'" [5].

Into Live Performance

When the technology of moonbouncing images using the MMSSTV was fully tested by Jan, the CAMRAS team and some international collaborators – Bruce Hálàsz PY2BS in Brazil, Daniel Gautschi HB9Q in Switzerland and Howard Ling G4CCH in the UK – I started working on ideas for using this great technology within a live performance. After some research I came up with the title for the project, 'OPTICKS', inspired by the 1704 essay by Isaac Newton on the reflections, refractions, inflections and colours of light.

During the first performances of OPTICKS in fact we used to moonbounce monochrome images of the seven colours of the light spectrum. In general however the title

aims at suggesting the phenomenon of reflection and refraction of the radio waves by the Moon's surface, through a poetic and philosophical link between Moonbounce and the light spectrum.

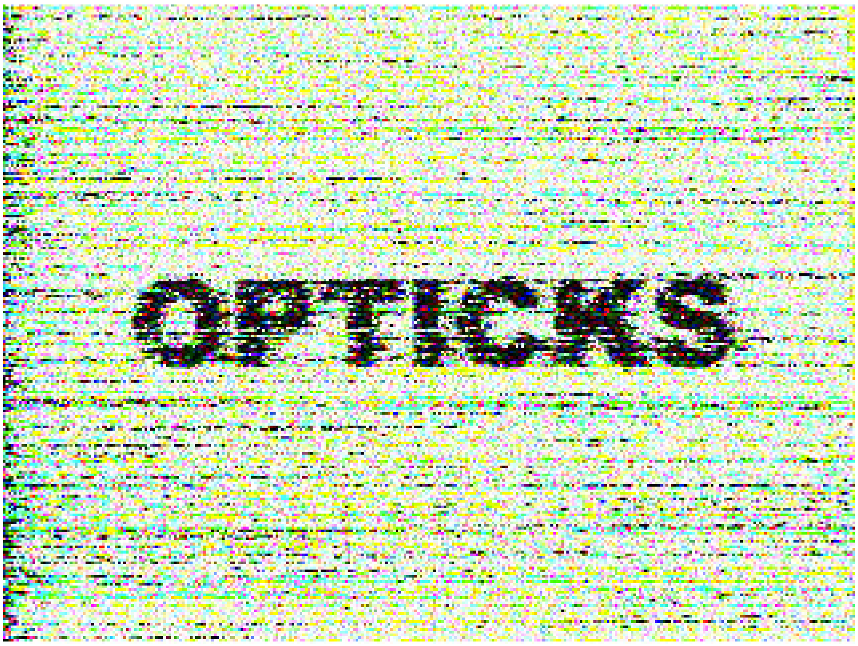

Figure 6: The OPTICKS title received by moonbounce

The first performance of OPTICKS took place on 30 October 2010 at 01:00 UTC at Extrapool, an experimental art venue in Nijmegen in The Netherlands. Images of the seven colours of the spectrum were sent by Howard Ling in the UK to the Moon, received by Jan at Dwingeloo radio telescope and projected in real time at the exhibition space. The building up of each colour (72 seconds for each image on 'Robot 72' mode in the MMSSTV setting) was accompanied by a sound score composed especially for the project and played live by Spanish composer Enrique Tomas (www.ultranoise.es).

Enrique composed a seven minutes score, especially tailored for EME technology, in which each minute corresponds to a musical note. The sounds were moonbounced and incorporated in the live show.

The idea of having a sound score was also inspired by the Newton's essay. The great scientist in fact believed in the hidden connection between the musical notes, the seven days of the week, the seven colours of the light spectrum and the seven celestial bodies known in his time. “Newton constructed the colour music disc dividing the spectrum into the seven colours [...] to be fitted in between the eight notes of an octave. The colour music disc in OPTICKS analogizes music to colour, just as its prototypes (of Plato, Ptolemy and Kepler) had connected music to planets and other qualities” [6].

Enrique, an experienced sound artist, enthusiastically took the challenge of composing sounds for moonbounce, and this is how he describes his experience: “The specifications of the project, with a maximum length of each piece of 72 seconds, a reduced spectrum between 400 and 2800 Hz and a monaural playback were an important constraint. Also I took into account the fact that my audios will be distorted due to the transmission through the atmosphere, the vacuum space and the reflection on the surface of the moon” [7].

This structure of the OPTICKS performance was used a few more times, including the show at the Amsterdam Planetarium in November 2010. The project however changes continuously so to be always different and unpredictable. Occasionally new collabora-

tors join in. After the first few live events I decided to replace the images of the seven colours of the spectrum with images submitted by the public attending the live event. Also I decided to replace the sound score with a verbal interaction with the audience, talking and answering questions.

During the show it is possible to hear in the background the sounds produced by the MMSSTV while the images return from the Moon. Because each colour corresponds to a unique tone in the software, the connection between colours and sounds suggested by Newton is intrinsic to the MMSSTV software.

During each live performance, Jan and the CAMRAS team appear in a video call and answer questions from the audience. Usually, after moonbouncing four of five images a pause is needed, in fact the power amplifiers and coax cables become very hot and need to cool down to avoid burning. Every OPTICKS event is a bit of an adventure, and we always experienced some technical problems either before or even during the live event. The problems are sometimes caused by a slow Internet connection (the images in fact are received live at any location thanks to a remote desktop control software called *TeamViewer*); or at other times there are problems due to high winds at one of the locations involved, or other technical failures at one of the stations. However, despite the complex technicality we never had to cancel a single performance so far!

Jan, Howard, Bruce and I have presented OPTICKS many times already, always with the enthusiastic response of the audience. One of my favourite performances was in collaboration with RAI Radio 2 programme 'Rai Tunes', directed by Italian DJ Alessio Bertallot. The programme can be followed both on the radio and on the web where it is possible to see the video for the event. The images submitted by the radio listeners, including some iconic images from popular culture, such as Pink Floyd's 'The Dark Side of the Moon' album cover, were sent to the Moon by Howard in the UK and received by Jan at Dwingeloo while some classical and pop music tunes accompanied the event [8].

One of the most interesting performances of OPTICKS so far was presented as part of Global Astronomy Month (GAM) 2012 in collaboration with Astronomers Without Borders [9]. For this occasion CAMRAS collaborated with Prof. Lech Mankiewicz, together with radio operators from ARISS Polska: Armand Budzianowski SP3QFE, Andrzej Matuszny SP6JLW, Jacek Masłowski SP6OPN and Paweł Matuszny SQ6OPG. The Polish team in a few weeks upgraded their equipment in order to participate in the live Visual Moonbounce performance scheduled for the 28 April 2012 at 18:00 UTC.

Several tests conducted by Jan and Armand preceded the event. The reliability of the Internet connection was one of the main technical issues the Polish team needed to solve, their station being located in the middle of a forest, also they had to find out what power levels could be safely used in order to send SSTV without overheating their amplifiers.

The OPTICKS live performance for GAM 2012 was presented live from Dwingeloo radio telescope: inside the cabin, CAMRAS radio amateurs Dick Harms, Theo Dekkers, Eene de Weerd, together with Jan, radio astronomer Roy Smits and myself, presented the event on Ustream for an international audience, moonbouncing images submitted by people of all ages and from all around the world. During the live event the moonbounce activities were temporarily paused for transmitting the image of Dwingeloo radio telescope followed by images of the primary colours (Red, Yellow, Blue) to a star called Upsilon Andromedae, 44 light years away. The Dwingeloo antenna rotated to track this star – together with the cabin and all of us inside – in front of the astonished audience following the event on the web. Upsilon Andromedae is believed to be hosting four planets, one of which, we hope, will receive the images in 2056 (centenary of the

Dwingeloo radio telescope official opening) and perhaps it may respond sometime in 2100.

For the OPTICKS performance for GAM 2012, the Polish team surprised us all with a special call sign, starting with the prefix of their country, SN2012GAM, that was used on some of the images moonbounced during that night. After the performance I printed the moonbounced images and sent them back as a card to the people from all over the world who submitted them, together with my message certifying the authenticity of the journey to the Moon and back. A certificate from both the CAMRAS and the Polish team has also been created to accompany the pictures. Some of the recipients of these images wrote back to me with a 'thanks' message, saying how much they appreciated the experience of being 'astronauts', even if only virtually. For further recordings and information, see [10–14].

As part of GAM 2012 I also presented a B/W video called 'le Voyage dans la Lune' (2011-2012), whose title is inspired by a famous French movie, made by George Méliès in 1902 and considered the first Science Fiction film in history [15]. Similarly, moon-bounce can be considered the first form of Space travel that allowed humankind to 'touch' another celestial body, by means of radio waves. My version of 'le Voyage dans la Lune' is composed by 26 images of the lunar phases taken by Michael Oates (Manchester Astronomical Society) who kindly offered them to me for the project. The 26 images have been moonbounced from Brazil to Dwingeloo in September 2011, using the SSTV mode B/W 12. I joined the moonbounced images together into a moving sequence and added the sound which has been provided by JAXA (Japan Aerospace Exploration Agency). The sound is called 'Moonbell' and uses laser altimeter data from one of the sensors of the lunar orbiting satellite Selene/Kaguya, transforming the altitude data into musical intervals [16]. The area I chose to 'sonify' is on the far side of the Moon, starting at the Korolev crater and continuing across the highest point. I used a very slow version of the sound in order to suggest the rhythmic steps of someone walking on the Moon.

Since the very first experiment on 6 December 2009, Jan, Bruce, Howard, Daniel and Armand sent many images to the Moon and back, not only for OPTICKS and for my artistic research but also for Visual Moonbounce enthusiasts, including Patrick Barthelow AA6EG who is proposing to use this technology for STEM education.

The Future

The future of Visual Moonbounce is already looking very interesting. The video 'le Voyage dans la Lune' is my very first attempt to use Moonbounce with moving images. However Jan, Armand and I have been discussing possibilities to moonbounce short films in a near future.

Besides my suggestions of using video clips and possibly 3D effects, Jan, Bruce, Howard and Armand are also developing ways to receive pictures with higher definition. Here is an example:

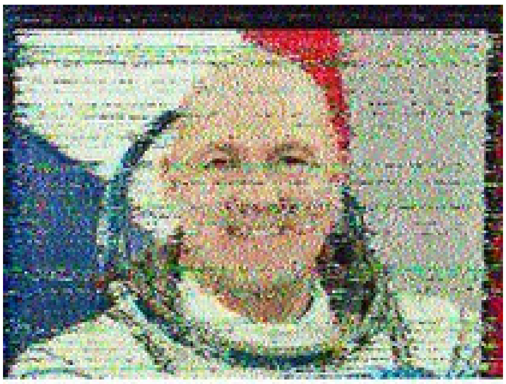

Figure 7: André Kuipers' portrait moonbounced using Robot 72 mode

This image of Dutch astronaut André Kuipers was first moonbounced by Jan on 25 February 2012 using the MMSSTV software in 'Robot 72' mode, taking 72 seconds for the whole picture. Jan also tried the 'Scottie DX' mode, taking 269 seconds and so promising better image quality, but the first attempts were spoiled by the changes in Doppler shift over this rather long time period. By careful manual correction (like many operators do with drifting digital EME signals that otherwise would be undecodable) it was possible to receive a nearly perfect picture:

Figure 8: Same moonbounced image as Figure 7,
using Scottie DX mode with continuous manual Doppler correction

After a live OPTICKS performance, Howard G4CCH also tried both a Scottie DX picture (269 seconds) and a picture in the faster Scottie 1 mode (110 seconds). The difference is visible but not very big, so Scottie 1 might be a nice higher-quality alternative to Robot 72 and takes only about 40 seconds more.

Conclusion

Experimenting is an important process for artists, radio amateurs and scientists alike.

Something that started as a playful experiment for an art project might lead to many interesting pioneering ideas in this fascinating technology called Moonbounce, and beyond even that.

Being a small part of this adventure is for me an amazing experience. I will never be grateful enough to CAMRAS, Jan, Daniel, Bruce, Howard and Armand for making 'visible' the journey to the Moon and back.

References

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2. http://en.wikipedia.org/wiki/Communication_Moon_Relay
3. http://history.nasa.gov/SP-4217/ch2.htm
4. Gebhard, *Evolution of Naval Radio-Electronics*, pp. 117-18
5. Andrea Mancini IW4CJM, *Writing on the Moon at 10GHz with Alice software*,13th EME Conference (Florence 2008)
6. **Niels Hutchison,** *Colour Music: Music for Measure*, 2004.
7. http://www.opticks.info/blog/?page_id=155
8. http://www.youtube.com/watch?v=s92lLLgFuOs
9. http://www.astronomerswithoutborders.org/gam2012/all-programs/1071-opticks-2012.html
10. A recording of the OPTICKS performance for GAM 2012 (unfortunately the first ten minutes are missing): http://www.ustream.tv/channel/opticks2012
11. Also a nice video made by Armand about the GAM 2012 event can be viewed here: http://www.youtube.com/watch?v=-6-a8ygDKrA
12. An article about the same event in Polish: http://sp3qfe.net/
13. Results of the ongoing experiments on SSTV are often published by CAMRAS in the weekly bulletin: http://www.camras.nl/
14. Updates and further information on the OPTICKS project can be found here: www.opticks.info
15. https://vimeo.com/41287703
16. *Moonbell: Listening to the Topography of the Moon*: http://wms.selene.darts.isas.jaxa.jp/selene_sok/about_en.html

In the longer version on the Conference DVD are Appendices with further comments from PA3FXB, HB9CRQ, PY2BS and the team at SN2012GAM.